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HYDROCARBON REFORMER PERFORMANCE SENSING SYSTEM

TECHNICAL FIELD

The present invention relates to reformers for converting hydrocarbons such as gasoline into hydrogen and other gases; more particularly, to hydrocarbon reformers for supplying gaseous fuels to fuel cells; and most particularly, to a sensing system for monitoring the completeness of hydrocarbon reformation in such a reformer.

BACKGROUND OF THE INVENTION

Fuel cells for catalytically combining elemental hydrogen and oxygen to generate electricity are well known. In so-called proton exchange membrane (PEM) fuel cells, the protons migrate through a membrane and combine with oxygen at a cathode. In so-called solid oxide fuel cells (SOFC), oxygen anions migrate through a solid oxide electrolyte layer and combine with hydrogen at an anode. In both types of fuel cells, gaseous hydrogen is provided to the anode surface. A common means for forming hydrogen in fuel cell systems is through catalytic partial oxidation (known in the art as "reforming") of hydrocarbons such as gasoline via the following non-balanced equation:

$$C_nH_{n+2} + O_2 \Rightarrow H_2 + CO \qquad \text{(Eq. 1)}$$

A PEM fuel cell is intolerant of CO, which can be removed in known fashion. An SOFC can utilize both H_2 and CO as fuel sources, being oxidized to H_2O and CO_2, respectively.

A potential problem exists is providing hydrogen via a catalytic reformer in line with either type of fuel cell. As a reformer ages in use, the catalyst tends to become

less efficient, and the reformate stream may contain a small percentage of non-reformed hydrocarbons. Fuel cell anodes are sensitive to the presence of hydrocarbons, which are readily converted to graphitic carbon, poisoning the catalytic sites of the anode. It can be costly, inconvenient, and time-consuming to replace or regenerate the poisoned anodes in a fuel cell stack.

What is needed in the art is a means for monitoring the gaseous output of a fuel cell reformer to determine when reformer inefficiency becomes a danger to the health of the fuel cell anodes.

It is a principal object of the present invention to prevent significant anode poisoning in a fuel cell system by monitoring and alarming hydrocarbon levels in reformate being provided to the fuel cell system.

SUMMARY OF THE INVENTION

Briefly described, in a fuel cell system wherein a hydrocarbon reformer supplies reformate to a fuel cell stack, a small portion of the reformate flow is diverted for analysis by a hydrocarbon analysis system. An incompletely-reformed reformate may include a variety of hydrocarbon compounds, including methane, in addition to hydrogen and carbon monoxide. However, it is the intent of this invention to measure only the dysfunctional reformer output methane, CH_4, as an indicator of the overall performance level of the reformer.

A methane sensor of the invention may be of any known quantitative type, including, but not limited to, catalytic, optical, and solid oxide electrode. A currently preferred embodiment includes a catalytic combustion sensor. Combustion air at ambient pressure is combined with the diverted reformate. Air and reformate are delivered quantitatively in a fixed ratio to the sensor, preferably via a double-headed positive displacement pump. When the fuel cell system is idle, the pumps positively close off flow of any reformate trapped in the lines that would otherwise escape past the sensor and into the environment.

The system provides alarm means to protect a fuel cell stack from elevated levels of hydrocarbons in the reformate stream. Preferably, an alarm is indicated when methane exceeds 1% by volume of the stream, and the reformer and fuel cell are shut down when the methane volume exceeds 3%.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example, with reference to the accompanying drawing, in which:

FIG. 1 is a schematic drawing of a reformate methane monitoring and alarming system in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a conventional fuel cell stack 10 is supplied with reformate from a conventional reformer 12 via line 14. Stack 10 is also supplied with air from a conventional main air blower 16 via line 18. Exhaust products from stack 10 are passed via line 20 through a clean-up exhaust treatment 22 to ensure that the exhaust products are environmentally acceptable. The process and apparatus as described thus far are well known in the prior art.

Attached to the conventional fuel cell system is a system 24 for online monitoring of the methane content of the reformate being generated by reformer 12. A methane monitor 26 is provided; in the presently-preferred embodiment, monitor 26 is a catalytic sensor, for example, Model No. CGI-201, available from Bascom-Turner Instruments, Inc., Norwood, Massachusetts, USA. Of course, other types of methane sensors or monitors are fully comprehended by the scope of the invention.

A catalytic sensor functions by catalytically combusting the methane in the presence of oxygen. Therefore, a combustion mixture having a known ratio of

reformate to oxygen must be supplied to the sensor. Line 28 feeds from reformate supply line 14 to provide a slipstream flow of representative reformate to a first positive displacement pump 30. Air is supplied to a second positive displacement pump 32. Preferably, pumps 30,32 are ganged with a common drive 34 as a two-headed pump, such that the proper and fixed ratio of reformate to oxygen is assured by proper sizing of the pumps. Preferably, the air flow is set such that the hydrogen/oxygen lower explosive limit (LEL) of 4% hydrogen is never exceeded. The outputs of pumps 30,32 are joined and supplied to methane monitor 26 via line 36. Excess mixture is sent via line 38 to exhaust treatment 22, as is mixture having passed through monitor 26, via line 40. Monitor 26 includes an internal third positive displacement pump 42 for metering a desired flow of the reformate/oxygen mixture through the monitor sensor for analysis.

Preferably, the drives for pumps 30,32,42, as well as the sensor itself, are controlled conventionally via an Electronic System Controller 44. A monitoring and alarm circuit therein can display continuously the actual methane content of the reformate stream and an annunciator 46 can be set at any desired alarm and action set points in known fashion. Optionally, the monitoring system can be programmed to relay feed back signal 48 to controller 44 so that fuel cell 10 can be shut down or placed in a sub-operating mode such as, for example, by shutting down or placing reformer 12 in a stand-by mode.

The currently-preferred Bascom Turner sensor has the following desirable characteristics. It can detect methane in the reformate of the full range from 0% to 100%. It has a sensitive scale with rapid response. It has automatic zero adjustment and is automatically self-testing. The internal pump drive is intrinsically safe, and the entire unit is rated C1D1, Groups A,B,C,D.

The dew point of reformate in the slipstream is approximately 100°C, and the maximum temperature of the sample gas for the sensor is above 325°C, so condensation in the apparatus is not a problem. The sensor measures percent methane gas in two ranges: between 0.05% and 4.0% by volume, and between 1% and 100% by volume. The measurement step in both ranges is 0.05%. The electronics for

the sensor preferably are housed with the Electronic System Controller in a conditioned space not exceeding 45°C in temperature.

In an operative example, reformate is provided to sensor 26 via pump 30 at a slipstream flowrate of 0.299 standard liters per minute (slm) and air is provided to sensor 26 via pump 32 at a flowrate of 2.24 slm. The reformate species concentrations and flowrates are:

N_2	60%	0.179 slm
H_2	16%	0.048 slm
CO	16%	0.048 slm
CO_2	6%	0.018 slm
CH4	2%	0.006 slm

The theoretical air flow for complete combustion is 1.87 slm. Assuming 20% excess air to keep the mixture below the hydrogen LEL, the actual airflow rate to be mixed with reformate is 2.24 slm.

In this example, the monitoring system is in alarm because the measured methane level is 2%.

While the invention has been described by reference to various specific embodiments, it should be understood that numerous changes may be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not be limited to the described embodiments, but will have full scope defined by the language of the following claims.